One Standard to Rule Them All:

Evaluating the Society for Ecological Restoration's Native Seed Standards

Noe I. van Alphen

Campus Fryslân, University of Groningen

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Dr. Carol Garzon Lopez

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Abstract

Supporting ecological restoration is crucial in the U.N Decade for Ecosystem Restoration. The supply of native seeds represents an important aspect in ecological restoration that requires global attention. The Society for Ecological Restoration's International Principles and Standards for Native Seeds in Ecological Restoration (Seed Standards) aim to facilitate successful and transparent seed supply chains. However, studies evaluating these standards remain scarce. Hence, this study aimed to fill the gap in literature by using Auroville's unique seed system as a case study to critically evaluate the appropriateness of the Seed Standards. The results showed that the Seed Standards lack socioecological nuance and exclude local knowledge systems. The Seed Standards' highly technocratic nature and tendency to overlook the restoration challenges of highly degraded ecosystems makes them unattractive to seed system practitioners. The Seed Standards prioritise a market-based paradigm that does not align with informal seed systems. These results demonstrate that local and traditional knowledge systems need to be foregrounded in science, and that standards for native seed systems need to prioritise community-led, collaborative, and diverse knowledge system principles.

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Introduction

Standards are all pervasive across modern society: from organic coffee bean farmers who must ensure certain environmental conditions in order to sell their beans, to presidential candidates that need to follow standardised campaigning rules. The fields of conservation and ecological restoration science are no exception to this trend, as demonstrated by recent initiatives such as the Global Biodiversity Standard (https://www.biodiversitystandard.org/) and the Standards for Ecological Restoration (Gann et al., 2019). These mechanisms are often presented as important solutions to tackle biodiversity loss and climate change. But standardisation entails the production of uniformity (Wattnem, 2016), which runs counterintuitively to the rich diversity of biological systems. So are these standards really appropriate across diverse socioecological contexts? This thesis aims to shed light on these questions, by critiquing the Society for Ecological Restorations's International Principles and Standards for Native Seed in Ecological Restoration (Pedrini et al., 2020).

In 2019, the United Nations General Assembly declared that the years 2021 to 2030 would be the Decade on Ecosystem Restoration (UN-DER), with the aim to reverse ecosystem degradation worldwide and to raise awareness about the importance of effective ecosystem restoration (United Nations, n.d.). Ecosystem restoration is facilitated by the closely related science of restoration ecology (Zerbe, 2022). The Society for Ecological Restoration (SER), the leading global authority in the field with over 5000 members in 130 countries (*Society for Ecological Restoration*, n.d.), defines ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Gann et al., 2019).

The supply of seed from source to restoration site is a very important step in ecological restoration, and is referred to as the seed supply chain (Pedrini et al., 2020). The importance of ethically sourcing genetically diverse native seed for restoration projects, and

maintaining seed genetic diversity in restoration projects has been studied extensively over time (Crawford & Whitney, 2010; Lippitt et al., 1994; Nevill et al., 2018; Stimm et al., 2008; Thomas et al., 2014). Natural ecosystems generally host large amounts of genetic diversity within species, and because the goal of ecological restoration is to replicate a reference ecosystem, this genetic diversity must be maintained in the restoration site (Pedrini et al., 2020). On the other hand, the over extraction of genetic material from ecosystems compromises the ecosystems self-sustaining natural regeneration abilities (Neville et al., 2018). Most restoration projects need to actively source seed from reference ecosystems, to then process (or propagate) and transport those seeds (or seedlings) to the restoration site (Chazdon, 2014).

To guide native seed supply for ecological restoration, the SER published the International Principles and Standards for Native Seeds in Ecological Restoration in 2020, herewith referred to as the Seed Standards. These guidelines cover the entire process from ethical seed collection to the sowing of seed on site (Pedrini et al., 2020). The Seed Standards were developed as a companion to the broader International Principles and Standards for the Practice of Ecological Restoration, herewith referred to as the Ecological Restoration Standards or the ER Standards (Gann et al., 2019). The Seed Standards focus specifically on the native seed supply chain, while the ER Standards address ecological restoration more generally.

While there is extensive criticism of the standardisation of agricultural seed (Wattnem, 2016), there appears to be no scholarly literature addressing the potential risks or unintended consequences associated with the standardisation of native seed in ecological restoration.[1]

[1] Some may argue that criticisms of agricultural seed standardisation may not apply to the native seed sector because significantly different standards exist for native seed and agricultural seed production due to their diverging priorities. In the agricultural seed supply chain, seeds are selectively produced on the basis of their desired function as a food or cash crop. Therefore, maintaining strict genetic purity of domesticated agricultural seeds is usually the main priority (Pedrini et al., 2020). On the other hand, native seed production for

Wattnem (2016) describes how the biological and socio-political commodification and monopolisation of agricultural seeds worldwide has led to the systematic erosion of seed sovereignty. Agricultural seed laws in the EU, for example, institutionally marginalise seed systems to the point that it is almost impossible to legally sell non-homogenous local varieties (Wattnem, 2016). Countries in the global-south have been pressured by Western institutions such as the World Trade Organisation to adopt similar seed policies for the sake of food security and development. In Colombia, local seed laws are so strict that farmers are essentially prohibited from exchanging any seed that is not certified according to the standards set by the government. Seed standards essentially outlaw informal seed systems, which are those that operate outside of regulatory frameworks (Wattnem, 2016). The power-laden standardisation of agricultural seed has widespread socioecological consequences, while invalidating and eliminating local knowledge. There has been significant critique and resistance to such standards in Colombia and the rest of the world (Wattnem, 2016).

Considering the widespread objections towards status-quo agricultural seed standards (Watten, 2016), the lack of literature evaluating native seed standards for ecological restoration, and the importance of critical discourse around standards and their effects on socioecological systems (Busch, 2013), this paper evaluates how the Seed Standards clash with the socioecology of local ecological restoration projects. Socioecology deals with the dynamic character of the interactions between society and nature (Olmos-Martínez & Ortega-Rubio, 2020). Applying a socioecological lens enables an interdisciplinary discovery

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ecological restoration seeks to preserve a wide genetic variety (Pedrini et al., 2020). However, despite their differences, their overriding similarities do warrant a comparison. Both types of standards deal with the common category of seeds where there is often overlap between domesticated agricultural seed and wild native seed. Both aim to regulate the production of seeds in a supply and demand market setting, both have been overwhelmingly produced in the West, and both are imposed (or envisioned to be imposed) across the globe in various local contexts (Cross et al., 2020; Wattnem, 2016).

of the highly interconnected and co-constructed social and ecological realities (Kates, 2001). Throughout the literature on native seed supply, numerous scholars have highlighted the importance of promoting local and traditional knowledge throughout policies and project implementation (Schmidt et al., 2018; Teixidor-Toneu et al., 2023; Urzedo et al., 2021; Wattnem, 2016). This paper is guided by such literature, and refers to local knowledge as more place-based, and traditional knowledge as more intergenerational (Gann et al., 2019). However, these definitions are rather fluid and interrelated.

I present a case study of a unique restoration project to develop a qualitative discussion around the limitations of native seed standardisation. Auroville, an experimental township in South India founded in 1968, was established to promote human unity (Clarence-Smith & Monticelli, 2022). A major focus has been the restoration of the region's original Tropical Dry Evergreen Forest (TDEF), a rare and fragmented ecosystem once widespread in coastal Tamil Nadu. Through seed collection from remnant temple groves, residents developed a unique, community-based seed system to support reforestation (Blanchflower, 2005). I choose the term 'seed system' to describe Auroville's seed supply chain as it is more accurate and affords greater breadth for analysis. This paper explores how Auroville's seed system, shaped by local knowledge, socioecological nuances, and collaborative networks has been successful while it does not align with the Seed Standards, highlighting the need for a re-evaluation of the framework and priorities set in the Seed Standards.

This thesis is guided by the research question: *How are international native seed standards appropriate in distinct local contexts like Auroville?*

In the following background section I introduce the case study, Auroville's restoration project, with a focus on the development of its seed system through time. Next, I describe the landscape of native seed standards before introducing the Society for Ecological Restoration's

Seed Standards. Although there is limited literature evaluating the Seed Standards themselves, I review papers which evaluate the ER Standards to further justify this research. To set the stage for this study, I question the socioecological paradigm that the Seed Standards are foregrounding. Next, I explain the methods used to construct and analyse the case study, which include employing the Seed Standards as a framework for analysis. In the results chapter, Section 1 compares and contrasts the principles and guidelines of the Seed Standard with the practices and priorities of the Auroville seed system. Section 2 of my results dives deeper into the knowledge systems of the Auroville seed system, and how these challenge the paradigm of the Seed Standards. In the discussion, I explain the relevance of the results, and connect these with further literature before presenting concluding remarks.

Background

Auroville Case study

Auroville is a unique international township that was founded on a desertified plateau on the east coast of Tamil Nadu in South India in 1968. Auroville was established by Mirra Alfassa, spiritual collaborator to Indian philosopher and guru, Sri Aurobindo, whose work on spiritual research on the evolution of consciousness inspired the experimental township as a project to realise human unity. A unique governance and social structure has been developed in Auroville, where residents live as voluntary workers and have their basic needs met in return. There is no private property in Auroville, all lands and assets are held for "humanity as a whole" by the Auroville Foundation and stewarded by residents. The Auroville Foundation, responsible for decision-making in Auroville, consists of three bodies: the Governing Board and International Advisory Council (both government-appointed), and the Resident Assembly, which includes all Auroville residents over the age of 18 (Clarence-Smith & Monticelli, 2022). Today, around 3000 people from more than 60 nationalities, nearly half of which are Indians, currently live and work in Auroville (Clarence-Smith & Monticelli, 2022). Auroville

now owns a patchwork of around 3000 acres of land interspersed with privately owned agricultural land and villages. From a sparse landscape, today there is more than 1300 acres of forest in Auroville, a testament to Auroville's commitment to soil conservation, water conservation and reforestation. Hundreds of native flora species have been reintroduced in the area, many of which are regenerating across and beyond the Auroville plateau, attracting a rich diversity of fauna (Blanchflower, 2005).

Four hundred years ago a Tropical Dry Evergreen Forest (TDEF) stretched across what is now the Auroville area. Local lore tells stories of thick jungles where tigers and elephants roamed. Unfortunately, over the course of India's colonial and post-colonial history, agricultural and urban expansion destroyed virtually all the forests of the Tamil Nadu plains, including the Auroville area. The most endangered ecosystem in India, only 0.2% of the original TDEF ecosystem remains and can qualify as pristine, yet highly fragmented sites (Blanchflower, 2005; Blanchflower, 2018). These small patches of remaining TDEF are found in and around sacred temple sites (temple groves). The level of disturbance and fragmentation of these temple groves is very high, but they still hold valuable genetic resources and represent the most appropriate local reference ecosystem (Baldwin, 2022). The temple groves and TDEF ecosystem was relatively unknown and understudied when Auroville was inaugurated on a denuded plateau (see figure 1). As restoration projects took root over the years, restoration practitioners in Auroville contributed greatly to the study and conservation of the TDEF through research, education, restoration projects, and advocacy (Blanchflower, 2005).

Figure 1

Auroville Area in the Late 1960's

Note. Photo credit to Auroville Archives

Auroville's Seed System Through Time

In the early 1970's, some of the first residents in Auroville started collecting seeds from the surrounding areas to grow trees. They collected seeds from nearby temple groves and reserve forests to plant whatever would grow in the hot and unforgiving climate (Blanchflower, 2005). Over the years Auroville's seed system progressively grew, in tandem with major water and soil conservation projects. Larger nurseries were set-up in Auroville and thousands of trees were grown and planted across the Auroville plateau. Finally, in the 1990's, a large drive to systematically survey all the temple groves was undertaken by Auroville foresters with funding and support from various local, national and international organisations (Blanchflower, 2005). Through this exercise, the species composition and structure of the TDEF temple groves as a reference ecosystem became clear. Thousands of seeds were collected from these temple groves and propagated in tree nurseries throughout Auroville

(Blanchflower, 2005). The Auroville seed system thus emerged from humble beginnings, and has been growing organically since its inception.

Fifty years after its foundation, Auroville's reforestation efforts have been hailed as one of the longest on-going reforestation projects in the world, receiving international acclaim for transforming a desertified plateau into a thriving TDEF ecosystem (Clarence-Smith & Monticelli, 2022; De Sousa E Castro, 2020; Kapoor, 2006; Kothari, 2022; Nagy & Szabó, 2019; Nagy, 2018). The landscape is essentially unrecognisable today (see Figure 2). More than 100 species of birds, 200 species of butterflies, and many mammals and reptiles have returned to the previously denuded landscape (Blanchflower, 2005). Auroville's forests are a living seed bank for the TDEF ecosystem, and many experts have speculated that they contain the richest biodiversity of TDEF species in India (P. Blanchflower, personal communication, April 17, 2022; R. Walker, personal communication, May 2, 2022).

Figure 2

Auroville Area in 2022

Note. Photo credit to Auroville Forest Group

Auroville's forests are made up of a patchy network of about forty different forest areas, each managed by a respective steward/stewards who together constitute the Auroville Forest Group (FG). The FG's primary goals include planting and maintaining Auroville's forested areas, restoring and upholding biodiversity, conserving soil and water, and taking a lead in environmental education and innovation (*Auroville Forest Group*, n.d.). Through fundraising efforts and membership contributions, the FG pays for tree planting throughout Auroville's forests. Funds are distributed to nurseries and foresters to cover the cost of supplying seedlings and basic tree planting expenses (*Auroville Forest Group*, n.d.). This unique informal seed system has enabled effective forest management, nursery functioning and tree planting throughout Auroville.

Up until 2021, the organisational system described above was in place. However, since 2021, an unprecedented governance crisis has ensued between the Resident Assembly and the Governing Board. This struggle for decision making power in Auroville has led to the Governing Board rescinding the FG's legitimate status, and cutting forester's stipends (Auroville Media Liaison, 2025; Kothari, 2022). In pursuit of rapid infrastructure development, the Governing Board has cut 20,000 trees without Environmental Assessment Impacts, is obstructing tree planting initiatives and arbitrarily bulldozing sections of FG managed forests (Auroville Media Liaison, 2025; Bana, 2022). Despite its status being rescinded the Auroville FG still continues its work over the past four years, using mutual aid and fundraisers to cover expenses and manage Auroville forests (Auroville Media Liaison, 2025). In it's 50 years, Auroville's seed system has shown resilience over time and in the face of this recent crisis, which is a clear indication of its socioecological sustainability (Olmos-Martínez & Ortega-Rubio, 2020) This research aims to shine a light on the important work and structure of Auroville's FG and resilient seed system, as well as discuss them in reference to the Seed Standards.

Auroville's plant nurseries and the people involved in them represent the focal points of Auroville's seed systems: nurseries are the hubs where the collection, propagation, and distribution of plant material occur altogether. At present, between five to ten nurseries of various sizes operate within Auroville (*Auroville.org*, n.d.). Some are small nurseries which supply only one specific restoration site with seedlings. Others are medium-sized, while the largest, the Auroville Botanical Gardens (AVBG) nursery, supplies upto 50,000 seedlings a year for various projects inside and outside of Auroville (Blanchflower, 2018).

Figure 3

The Auroville Botanical Gardens Nursery

Note. Photo credit to author

SER Seed Standards

The Landscape of Native Seed Standards

Understanding national seed policy landscapes helps contextualise the emergence of the Seed Standards. Only a few countries have formal protocols for native seed production and trade (Nyoka et al., 2014). For instance, the U.S. Bureau of Land Management launched the Seeds of Success program in 2001 to standardise native seed collection and conservation. This led to the 2015 U.S. National Seed Strategy, which promotes genetically appropriate native seed use in restoration (Oldfield, 2018). However, national policies often face challenges. In Brazil, informal seed networks operate outside regulation due to burdensome documentation, a lack of seed labs, and limited quality testing guidelines (De Urzedo et al., 2019). In the Philippines, Gregorio et al. (2016) highlight poor policy support mechanisms, including delayed funding, weak seedling quality controls, and inadequate monitoring of nursery supply chains.

Similarly, at the international level, few standards exist for native seed governance. The Organization for Economic Cooperation and Development's (OECD) "Scheme for the Certification of Forest Reproductive Material Moving in International Trade" is applied by 30 countries but is primarily tailored to commercial forestry and agroforestry (OECD, 2024). It covers seed source documentation, genetic diversity, and handling protocols but is limited to 402 species, offering little relevance to restoration practitioners working with many more species across diverse ecosystems. In Europe, there is no unified policy to support native seed markets (Abbandonato et al., 2017)[2]. In the absence of relevant national and international native seed standards (Nyoka et al., 2014; Pedrini et al., 2020), and due to the SER's leading position in the field of ecological restoration, the Seed Standards become an important

[2] The European Native Seed Producers Association (ENSPA), founded in 2020, promotes access to high-quality native seeds across the continent. ENSPA's 14 member organisation uses the SER Seed Standards as a guide, with the document's lead author serving on its advisory board (*European Native Seed Producers Association*, n.d.).

document.

The SER's Seed Standards

The Society for Ecological Restoration's Seed Standards were published in 2020 to enhance the native seed supply chain internationally (Pedrini et al., 2020). The Seed Standards include four overarching principles with accompanying guidelines to optimise the seed supply chain from start to finish, from native seed sourcing to seed enhancement (see figure 4). The four principles are: 1) Seed Origin, Collection, and Cultivation, 2) Seed Processing and Storage, 3) Seed Quality, 4) Seed Enhancement: dormancy breaking, priming, and seed coating. Several specific guidelines are provided under these four principles, such as collecting no more than 10% of seed from wild annual populations per season (Pedrini et al., 2020). The Seed Standards also provide labels that are applicable to point-of-sale release of native seed, and pro-formas that can be used for labeling of native seed batches prior to sale.

Figure 4

The Interaction Between Restorative Activities and Key Steps in the Native Seed Supply Chain

Note. From Cross et al. (2020).

The Seed Standards were developed to facilitate the urgent development of robust,

effective, and ethical seed supply chains during this era of high global demand for restoration projects (Pedrini et al., 2020). The guidelines provide a synthesis of scientific information to ensure the appropriate origin and diversity of native seeds. Every seed counts, and every seed should be delivered to the right location at the right time. The motivation behind the development of the standards is to move towards a native seed market which can match the confidence and reliability of agricultural and forestry seed markets, "The underpinning principle for the standards is to provide buyers, end users and funding bodies with a level of confidence and reliability in the sourcing of quality native seeds similar to that enjoyed for crop and forestry species" (Pedrini et al., 2020). These are ambitious goals with large effects on the global native seed landscape, and as such deserve an extensive evaluation. Unfortunately, there appears to be no literature which critically evaluates the Seed Standards.

Critiquing the Ecological Restoration Standards

There is, however, literature which critically discusses the broader ER Standards (Gann et al., 2019), which is useful for this research because the Seed Standards are built on the foundation of the ER Standards. Higgs et al. (2018) point out that cultural practices should be given more attention in the ER Standards as they play an important role in ensuring restoration success. Higgs et al. (2018) also claim that the SER one-size-fits-all approach does not meet the needs of greater flexibility for diverse ecosystems and cultures.

Voicescu et al. (2022) interviewed Canadian restoration practitioners to explore their reasons for applying or not applying the ER Standards. According to their study, the main criticism of the ER Standards are its limited accessibility: the document has a global-north focus that is not sensitive to different cultural and development priorities of global-south countries. There is also an expertise bias: the document is geared towards people who already have professional background knowledge, excluding volunteers, students, community groups, etc. The study reports that practitioners feel that the structure of the document is overly

complex, lengthy, broad, and presents terminological contradictions with other existing documents on restoration. Some practitioners that work in heavily transformed and degraded ecosystems (open cast mines, etc) are discouraged that their work will simply never be able to meet the highest restoration continuum implied in the standards. Practitioners report that the document is not suitable for on-the-ground-work as it is overly focused on broad principles and that it does not add anything new to the work practitioners are already doing. On the other hand, some participants value the clear structure, consistent terminology, and their familiarity with and trust in the SER's work (Voicescu et al., 2022). The results of this study suggest that the Society for Ecological Restoration has a large task ahead in order to improve the accessibility, suitability and relevance of the ER Standards. This study shows the importance of analysing practitioners' perspectives to critically evaluate ecological standards.

Important Questions About the Seed Standards

There are large global implications of developing international native seed standards. The authors of the Seed Standards state that

> The principles and standards outlined in this document provide the foundation for the next logical step toward developing certification of native seed suppliers and native seed testing laboratories. Such certification approaches may be considered in future editions of these Standards. (Pedrini et al., 2020)

The Seed Standards serve as a foundational document upon which the global native seed industry could pivot towards the certification of native seed suppliers, transforming entire markets, industries, finance streams, and practices. This would have large implications for local ecologies, communities and restoration practitioners, qualifying the Seed Standards for extensive critique. The following pertinent questions must therefore be asked: Do the

standards and certifications fit diverse ecologies, cultures, socio-economic, and political realities? Is the marketisation of nature through native seed certification schemes a desirable outcome? Is the industrialisation and technological enhancement of seed systems a desirable outcome? How will the equal global access to understanding, implementing and benefiting from the standards and certification be guaranteed? These questions need to be studied first, if certification approaches will be considered in future editions of these standards.

The authors of the Seed Standards state that the standards can be adjusted according to local conditions (Pedrini et al., 2020). However, no studies appear to have been conducted to verify how and whether it is possible to adapt and apply the Seed Standards across new or existing diverse seed systems. This is where this research seeks to fill the gap by studying whether the Seed Standards align with Auroville's seed system, while reflecting on the global significance and local relevance of standardisation processes.

Methodology

Case study

In order to facilitate an in-depth and nuanced discussion of the Seed Standards, I chose Auroville as a qualitative case study. This case study was chosen specifically because it is a successful long-standing restoration project (De Sousa E Castro, 2020; Kapoor, 2006; Nagy & Szabó, 2019) with over 50 years of knowledge accumulation holding valuable and time-tested insights, and because of my field-based expertise of the Auroville seed system. I grew up in Auroville and spent several years working in various ecological restoration projects in Auroville. I co-managed a native tree nursery for two years, gaining a deep understanding of Auroville's seed system. I had frequent exchanges of information with all the major tree nurseries in Auroville, and this has informed the direction of this thesis. I chose to use this case study because I am uniquely positioned to provide a thick description of it (Geertz, 2008). I rely on my past field observations to enrich my analysis. This case study enables a

deep understanding of the practices and perspectives of local restoration practitioners, which are generally informed by their unique contexts. When perspectives and contexts cannot be isolated from one another, conducting a case study is highly appropriate (Baxter & Jack, 2015).

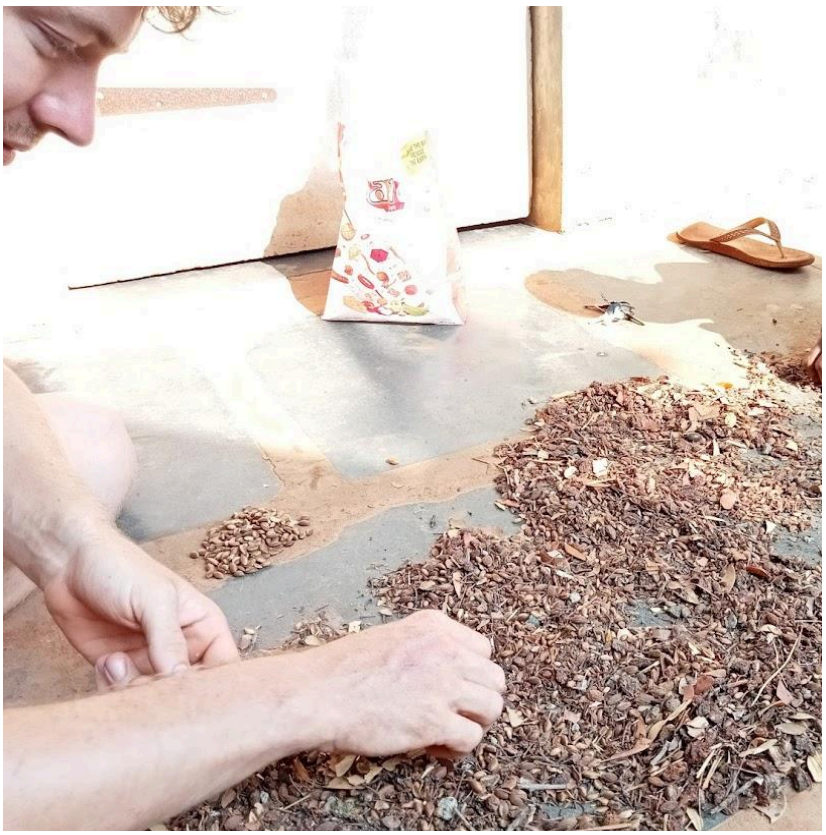
The unit of analysis for this case study is the present-day Auroville seed system, which operates throughout Auroville's community-based restoration projects in South India. All the individuals, tree nurseries, and organisations that are involved with native seed research, collection, propagation, distribution, and planting qualify as part of the Auroville seed system.

I used Auroville's seed system as an instrumental case study (Stake, 1995) which provides insight into the appropriateness and relevance of the Seed Standards. The case study is examined in depth, but its main function is to facilitate a critical analysis of the Seed Standards. It is important to note that the Auroville case study is not a typical case, and the results of this study are not directly transferable to other case studies.

The Auroville seed system does not follow the Seed Standards. This presents a potential design bias: common practice might suggest that in order to evaluate the effectiveness of an intervention, a case study where the intervention is already being applied should be used. However, this study's approach of predetermining an intervention is equally valid and used across conservation research (Van Heist et al., 2015; Piccolo et al., 2023). By predetermining the Seed Standards' intervention, the rich anomalous details of the case study are preserved, allowing a thorough analysis of the intervention in question.

Figure 5

Cleaning Seeds



Note. The Author cleaning a batch of native seeds during his work at the Ridge-Top nursery in Auroville. Photo credit to author

Interviews

I conducted four interviews as the primary source of data for this case study. I used purposive key informant sampling to select the interview participants: due to my personal involvement in Auroville's seed systems, I was able to confidently choose the interviewees for this research who would provide me with the most detailed account of the Auroville seed system. My criteria for inclusion was that interviewees had to 1) have a deep level of commitment to and expertise about Auroville's seed system, 2) be representative of Auroville's seed system stages (seed collection, nursery propagation, seedling distribution and planting) and scales (Large, medium, and small scale operations within the seed system), and 3) be representative of diverse race, gender, and age. I interviewed four restoration practitioners in Auroville: a seed collection and seed networking expert (Interviewee 1), the

director of a large scale nursery and restoration organisation (Interviewee 2), a long-time reforestation site steward who runs a medium scale nursery (Interviewee 3), and a long-time reforestation site steward who used to run a small scale nursery (Interviewee 4). Interviewee data is confidential and their identities have been kept anonymous.

Addressing Participant Bias of Case Study

In the study conducted by Voicescu et al. (2022), participants had relatively good knowledge about the ER Standards already, which allowed the researchers to conduct certain quantitative analysis about why the participants chose or chose not to use the ER Standards. On the contrary, for this research paper none of my interviewees were familiar with the Seed Standards specifically. This may seem like an inappropriate sample that compromises the validity of my research (Morse et al., 2002). I compensated for this potential weakness by describing the main objectives and guidelines of the Seed Standards to the interviewees before conducting the interviews. To further ensure rigor, I also chose not to make the Seed Standards the main focus of the interviews. Instead, I asked questions which enabled me to understand the context of the Auroville seed system in depth, including its detailed practices, such as collection and propagation methods. When I asked interviewees how they felt about specific guidelines of the Seed Standards, I made sure to explain these clearly.

Thematic Analysis

I performed an inductive thematic analysis (Castleberry & Nolen, 2018) of the interview data. Interview recordings were transcribed into text with AI software. I verified these transcriptions to ensure accuracy and precision as well as to familiarise myself with the data. I coded the interview data and three main themes emerged out of this process: practices, priorities and knowledge systems. When an interviewee explained their process of seed collection, this was coded as seed collection practices which I later placed under the theme ‘practices’. When an interviewee attributed importance to being part of a network of seed

collectors, I coded this as network priorities which I later placed under the theme ‘priorities’. Lastly, when interviewees spoke about how they learned, how they thought about their work, and the values and principles that guided their practices, I coded these respectively and placed them under the theme ‘knowledge systems’. Some codes were difficult to place: when an interviewee spoke about the governance crisis in Auroville impacting their work I placed this under the theme knowledge systems because it is related to the way they think about and ascribe value to governance.

I analyse the themes ‘practices’ and ‘priorities’ in Section 1 using the Seed Standards (Pedrini et al., 2020) as a framework. In section 2, I analyse the theme ‘knowledge systems’ in reference to literature around local and traditional knowledge of seed systems (Wattnem, 2016; Urzedo et al., 2021; Schmidt et al., 2018).

Frameworks for Analysis

In Section 1, the Seed Standards (Pedrini et al., 2020) are presented as a framework to compare and contrast its guidelines with the practices and priorities of the Auroville case study. This framework enables a clear contrast between key differences in practice and priority between the Auroville seed system and the Seed Standards. The Seed Standards framework is made up of four principles which are composed of twenty guidance statements. I advise the reader to refer to the open-access Seed Standards document (Pedrini et al., 2020) when reading this section of the analysis. Throughout this section I rely on a socioecological lens (Olmos-Martínez & Ortega-Rubio, 2020) to compare and contrast the Seed Standards with the Auroville seed system practices and priorities.

Throughout my research, I noticed that the Seed Standards framework was not equipped to analyse the theme of knowledge systems in Auroville’s case study. In section 2, I am attempting to demonstrate the divergent knowledge systems between the Auroville seed system and the Seed Standards. Throughout this analysis, I investigate the epistemic

inclusivity of the Seed Standards. The literature on local and traditional knowledge around native seed systems (Teixidor-Toneu et al., 2023; Wattnem, 2016) guides the analysis of this section.

Analysis

Section 1 - Evaluating the Seed Standards Against Practices and Priorities in Auroville

Principle 1: Seed Origin, Collection, and Cultivation

The Seed Standards insist on using only native species for ecological restoration. There are diverse practices regarding species nativity in Auroville. Some practitioners insist that only native TDEF species should be planted. However, most practitioners agree that while the focus should be on native species, non-native species provide multiple benefits to the ecological landscape such as nitrogen fixing, providing a pioneer canopy, and income generation from intermixed timber trees to sustain restoration activities. Several non-native plants are grown in nurseries throughout Auroville and play a vital role in supporting ecological restoration. In fact, the success of Auroville's reforestation efforts is largely attributed to a non-native 'invasive' species, the *Acacia auriculiformis*, which played a crucial role as a pioneer species during the early phases of restoration. The *Acacia* was able to thrive in the highly degraded soil and harsh climate of the Auroville plateau, improving soil conditions through nitrogen-fixing and leaf litter to the point where native climax trees could finally be planted under the conducive shade of the *Acacia's* evergreen canopy. As the native trees grew tall underneath the *Acacia*, its successional niche was completed. The *Acacia* has now stopped regenerating in Auroville's older forests. The Seed Standards fail to acknowledge that non-native seeds represent powerful opportunities for ecological restoration, and this foregrounds a narrow and inflexible approach to unique socioecological contexts of diverse ecological restoration projects.

The Seed Standards recommend documenting the source of each seed batch for point

of sales information. Interviewee's informed me that during the 1980's and 1990's the main nursery in Auroville at the time documented seed sources and tagged germination beds and seedlings in the nursery with their respective seed source information. In this way, they were able to observe differences in germination patterns between various seed sources. However, documentation requires considerable resources and small scale nurseries in Auroville struggle to implement it. The Seed Standards overlook the difficulty of implementation, and do not offer simpler alternatives. That being said, interviewees explained that there is a drive to improve documentation practices per seed batch throughout the propagation, distribution, and planting stages at the AVBG nursery in Auroville. The Seed Standards, when referred to as simply a guideline, may offer a positive reminder for seed system practitioners to consider more detailed and transparent practices.

It should be noted that documenting seed sources for point of sales/distribution information was not a priority for interviewee's that work in the nurseries of Auroville's seed system. Instead, practitioners were more concerned about documenting the species diversity of the precarious TDEF temple groves. The AVBG team published a website (https://auroville-tdef.info/) documenting the presence of TDEF species in each temple grove, their characteristics, their annual flowering and seeding patterns, etc. This resource helps seed collectors identify where and when they might find seeds of desired species. There is a clear divergence between documentation practices in Auroville and those prioritised in the Seed Standards. By imposing a standardised priority to document seed source for the purpose of sales, other context-specific documentation practices may be perceived as less important, stifling creative solutions designed to meet local needs. In a regular market context where there is a supplier and a buyer, providing point of sales information about seed source is a reasonable standard. However, Auroville's informal seed system replaces supplier/buyer relations with a more holistic model where suppliers distribute fully subsidised seedlings

within a tightly-knit community of restoration practitioners, rendering the market-based paradigm of the Seed Standards less relevant to Auroville's seed system.

Seed Collection from Natural Populations. The Seed Standards provide different guidelines for seed that is sourced from natural populations, and seed that is sourced through managed seed production (see next subheading). In natural populations, the Seed Standards recommend to collect seed from at least 50 individuals per species. This is impossible for many of the rare TDEF plants which constitute the Auroville seed system. As much as possible, Auroville's seed collectors have maintained genetic diversity by collecting from as many individual plants as possible. Some species like *Albizia amara* are abundant across many temple groves, so their genetic diversity is easy to maintain during seed collection. On the other hand, species like *Dimorphocalyx glabellus* are extremely rare and only a few specimens were found in very few temple groves. Considering the rarity of such species, seed collectors cannot collect from 50 individual species as recommended in the Seed Standards. One interviewee explained,

> We try to be as genetically correct as possible, but on the other side, we try to be pragmatic and realise we're dealing with sort of devastated ecosystems. So we sort of take what we can get whenever we can get it. (Interviewee 2)

The Seed Standards define a high benchmark for native seed collection, but they fall short in supporting the practical methods required in devastated or highly degraded ecosystems.

The Seed Standards recommend establishing seed transfer zones. In Auroville, the majority of native seeds are collected from within the TDEF zone: the Coromandel coastline of South India. This represents a relatively large seed transfer zone with distinct climatic and geological features. This practice is best described in the ER Standards as admixture

provenancing, which is suitable for highly disturbed ecosystems (Gann et al., 2019). However, some seed collectors in Auroville have vast native seed exchange networks that extend beyond the TDEF seed transfer zone and throughout South India and its various forest ecologies. One seed collector explains,

> No, our seed exchange is not restricted to the TDEF zone. If people want the seeds and I have them, I'll give them. Because TDEF plants are found in some deciduous forests. Some species are found all the way till Central India. (Interviewee 1)

Interviewees pointed out that since the genetic diversity of many local plant species in India has been diminished due to fragmentation and habitat degradation, introducing genetic material from distinct seed transfer zones might reduce the risk of inbreeding depression of some genetically degraded local species. This topic requires further research. It can be concluded, however, that practices in Auroville do not align with a strict delineation of seed transfer zones as recommended by the Seed Standards. Auroville's seed system is flexible, adaptive, and expansive when it comes to seed transfer zones, while the Seed Standards rigidly predetermine strict seed transfer zones. This represents another failure to adapt to unique socioecological contexts.

The Seed Standards recommend a collection ceiling of 10% for wild annual species. Interviewed seed collectors explained that there are a number of factors which determine how much seed they collect per individual in the wild. In very disturbed groves, there is little chance for seeds to germinate and survive. In such cases, seed collectors explain that collecting the majority of the seeds will ensure their survival and lead to greater restoration impact when propagated in the nursery and planted in protected areas. There are costs involved in travelling to far away groves for seed collection. Therefore, depending on the

amount of required seed, seed collectors sometimes collect up to half of the available seeds during the time that they are on site. In general, seed collectors operate with care and attention and adjust their collection methods according to species and site specific conditions. Interviewees reported that the Seed Standard's collection ceiling represents an arbitrary form of control which will only make collection processes even more tedious while missing unique ecological and socioecological nuances.

Managed seed production. The Seed Standards provide specific instructions to maintain genetic diversity in Seed Production Areas (SPAs), which are defined as managed wildstands and cultivated fields of native species. In Auroville, several nurseries collect native seed from the 1300 acres of locally reforested sites in Auroville, which could be categorised as cultivated fields of native species. But since these reforested areas are now more than 50 years old, they might also be categorised as wild stands. The Seed Standards do not provide enough clarity on how such areas should be categorised.

The Seed Standards indicate that measures need to be taken to avoid hybridisation of wild species with SPA species, and to avoid interspecific hybridisation amongst SPA species. If we treat reforested sites in Auroville as SPA areas, undertaking these measures is impossible due to the scale and extent of Auroville's restored forests. There is no way to isolate the forests from external pollinators, and there is no way to restrict inbreeding between species in the forest.

The Seed Standards indicate that a maximum of five generations should be collected from SPA's, in order to limit the risk of hybridisation and genetic drift. Some nurseries collect significant amounts of native seed from reforested areas. It is likely that in some cases the number of collections from SPA's surpasses five generations. Monitoring the number of times that seed was collected from specific plants presents difficulties within but also between nurseries since sometimes multiple nurseries collect seed from the same SPA. To resolve such

monitoring difficulties, one interviewee suggested the idea of an "e-seed" web-based system similar to the existing e-butterfly (https://www.e-butterfly.org/), which would enable shared documentation of seed collection between different nurseries. Seed collectors could geo-locate the plant they are collecting seeds from and add additional attribute data such as species name, collection date, amount of seed collected, etc. This data could be shared and accessed across the entire seed system to keep track of how many times seed from SPA plants has been collected and thus limit the amount of collections/generations produced to under five. This system would also help to increase knowledge about diverse seed sources and coordinate collection times, leading to improved genetic diversity of collected seeds and resilience of the seed system. Technology can help relieve some of the resource intensive demands of the Seed Standards. Interviewees were proactive about improving seed practices in context specific ways, while borrowing inspiration from some of the recommendations made in the Seed Standards. Some specific recommendations of the Seed Standards can therefore be adapted to unique socioecological contexts.

Principle 2: Seed Processing and Storage

The Seed Standard guidelines on processing and storage are less applicable to nurseries in Auroville, as most of the seeds collected are neither processed nor stored but instead sown directly into germination beds, trays, or seedling bags. This is largely due to the fact that many of the structural TDEF species produce recalcitrant seeds (Blanchflower, 2005), which are seeds that are sensitive to desiccation and low temperatures, and thus cannot be stored for more than a few months without losing viability or rotting, due to their high moisture and oil content (Subbiah et al., 2019). The Seed Standards clearly focus on the processing and storage of orthodox seeds, which account for roughly 80% of flowering plant species and are predominant in temperate regions (Subbiah et al., 2019). Although orthodox seeds are also present in tropical ecosystems, the recalcitrant seed trait is more commonly

associated with tropical species. As such, the Seed Standards appear to be more aligned with temperate contexts, and would benefit from addressing recalcitrance in greater depth to increase their relevance to tropical regions.

Principle 3: Seed Quality: Representative sampling, purity, viability, germinability, and seed weight tests

The Seed Standards provide an exhaustive protocol to ensure seed quality and facilitate planning for the quantity of seed needed. The guidelines suggest sampling seeds and testing each sample for purity, viability, germinability and seed weight with procedures and tools ranging from simple cut tests to specialised x-ray machinery. Such detailed protocols are mainly relevant for the purpose of sales of seeds from grasses and forbs which are directly sown into the ground. In the Auroville seed system context, where the focus is on trees and shrubs, such procedures have only been developed to the extent where they are locally relevant and beneficial.

In the early days of Auroville's seed system, simple germinability tests were carried out and seed weight was recorded. Germination knowledge was gained through accessible methods of trial and error and long term observation, without the use of x-ray machines or tetrazolium tests. Today, rather than focussing on increasing technical germination procedures as prioritised in the Seed Standards, practitioners in Auroville have prioritised local knowledge sharing: the AVBG has collaborated with India's Ecological Restoration Alliance (ERA) to create a publicly accessible database that shares knowledge about the germination processes for over 1200 local plant species (https://era-india.org/seed-germination/). Seeds are ranked with low, medium or high germinability. This helps collectors determine how many seeds they should collect to fulfill their desired quota of seedlings. Auroville's informal seed system prioritises practices that are pragmatic and locally relevant, while the Seed Standards set predetermined and resource-intensive priorities that do not fit diverse socioecological

contexts.

Other related quality protocols involving representative sampling, purity, and viability tests are not systematically carried out in Auroville because these are not relevant to practitioners. Viability tests are carried out on the spot: if seeds appear underdeveloped, if they appear damaged by insects, or if they float in water then they are most likely not viable and discarded. The Seed Standards' highly technical procedures are replaced by practical steps in Auroville.

Principle 4: Seed Enhancement: Dormancy Breaking, Priming, and Seed Coating

The Seed Standards recommend following a rigorous process to determine and treat dormancy of seeds, as well as documenting details about seed enhancement used for each batch of seeds. Several simple techniques of dormancy breaking have been experimented with and used in Auroville's seed system, such as scarification and flash boiling. For many species, seed priming is done by soaking seeds in a mixture of cow dung and water for a specific amount of time which varies per species. This is traditional knowledge that has been used to germinate seeds in Indian agriculture since centuries. Seed workers in Auroville have studied and applied this method successfully across many native seed varieties in Auroville. This practice deviates significantly from the Seed Standards' recommendations. The Seed Standards do not afford any mention or value to utilising local, traditional, or indigenous applied knowledge for seed enhancement. Although the ER Standards do encourage the use of traditional and local ecological knowledge for ecological restoration (Gann et al., 2019), these practices are excluded when it comes to the Seed Standards.

Section 2 - Evaluating the Seed Standards Against Knowledge Systems in Auroville

This section analyses the knowledge systems of Auroville's seed system while contrasting it to the Seed Standards. This section provides greater context and depth to the results of Section 1, by analysing the different knowledge systems which play a role in

shaping both the practices and priorities of Auroville's seed system. This section is guided by literature on local and traditional knowledge (Teixidor-Toneu et al., 2023; Wattnem, 2016)

All interviewees said that they relied on 'trial and error', 'common sense', and 'talking to people' to gain knowledge about seed system best practices. Some interviewees also noted that an intuitive type of knowledge slowly builds during their practice. For example, when attempting to germinate a new tree species, they can estimate what might be the best priming method according to their feeling of the seed, its hardness, size, and shape, and based on experiences of what worked well for other similar seeds. One interviewee explains:

> Common sense is quite good with seeds, I think. You know, it's not rocket science, apart from the ones that really you can't work out how to germinate them. So soaking, cow dung, all of those things. And I suppose, yeah, it's common sense, trial and error, and talking to people. (Interviewee 2)

The danger of standardisation is that local ways of knowing like those described above are deemed inferior and/or insufficient (Wattnem, 2016).

Another interviewee explains how she learnt about unique nursery practices by growing up amongst a community of reforestation practitioners:

> I knew the process of planting the seed in germination trays and filling the plastic seedling bags, how to mix the compost with topsoil, and how to screen the compost to make it fine so it fits in the bags. All of those things which I observed growing up, I kind of knew.. I had grown up watching them do it.. So I kind of had a natural understanding of the sequence of what one does in the year, according to the seasons. (Interviewee 4)

The interviewee essentially gained seed system knowledge through intergenerational exchange and place based experience. These are central tenets of local knowledge systems (Teixidor-Toneu et al., 2023), which are excluded in the Seed Standards. This largely reduces their epistemic inclusivity.

Auroville has a vast network of seed and knowledge exchange between various nurseries and restoration projects both within and outside of Auroville. This is a major method of knowledge accumulation and sharing. An interviewee explains that this is not always the case in India, “if you go to any business or nurseries, they're not very happy to share their knowledge” (Interviewee 1). They also explain that regular citizens also share information with seed collectors in Auroville when they observe seed available on trees of interest:

> I've got so many friends telling me that, oh, this is seeding there. This is seeding here, you can go collect them. Even when people just randomly go cycling, they see the seed and they text me, send me pictures.. This gives me more data to work with. (Interviewee 1)

Practitioners in Auroville use their wide personal networks to gather information about the seeds around them. Local knowledge systems enable dynamic and open networks that combine short and long distance exchange of seed and knowledge (Teixidor-Toneu et al., 2023). Both seeds and the essential knowledge associated with them, such as germination techniques, are conserved in this way (Teixidor-Toneu et al., 2023). Auroville’s extensive and open knowledge and seed network, enabled by its local knowledge system, is central to its success and provides social benefits to the community such as feelings of purpose and

togetherness. Unfortunately the Seed Standards do not offer support to seed and knowledge exchange networks.

Some practitioners in Auroville understand seeds in a creative, intuitive, and emotionally meaningful manner, which stands in tension with the technocratic logic of the Seed Standards. One of the interviewees explains,

> We're trying to inspire people through beauty and the magic of nature. And I feel like it's a creative act. And so seeds are part of that creative act. And seeds have an amazing narrative that is fascinating and there's a joy to germinating things and propagating things. (Interviewee 2)

This sense of magic, joy, creativity and fascination subsides when I ask the interviewee about seed standardisation. He says that he has a slight aversion towards seed standardisation protocols which, to him, represent exaggerated regulations, overly technical procedures and unnecessary safety protocols which clash with his belief in the resilience of nature and the joy of propagating things. For example, he acknowledges concerns about propagating and planting non-native species but believes the world is already in constant flux, suggesting that the caution written into standards can quickly become excessive. The Seed Standards are unattractive to restoration practitioners in Auroville due to their perceived technocratic character, which mirrors the global struggle for seed sovereignty by farmers across the globe (Wattnem, 2016).

Auroville's seed system is grounded in collective values that highlight the need for stronger guiding principles in the Seed Standards. Interviewee's identified collective will, fraternity, and mutual support as important principles of Auroville's seed system. These principles have enabled a diversity of ecological restoration practices across Auroville which,

although greatly threatened by the present governance crisis, continue to be highly relevant. In this sense, the Seed Standards' highly descriptive principles, such as ‘Seed Origin, Collection, and Cultivation’ hardly qualify as guiding principles for seed systems. While it may be difficult to capture Auroville’s unique principles in a document that is meant to be internationally applicable, it is nevertheless important that such a document should encourage a set of strong principles to ensure community-led, collaborative, and diverse knowledge system principles for seed system practices. These principles could then contribute to safeguarding seed systems from unwarranted political interference.

Auroville’s principles of collective will, fraternity and mutual support toward one another at the same time enabled opportunities for people to be autonomous and creative. Out of this supportive community base, individuals were able to practice autonomy in developing their unique practices of restoration in Auroville. Because there were no predetermined practices for ecological restoration, interviewees explained how a diversity of forest management practices evolved across the 40 sites managed by the Forest Group. In turn, this has created diverse ecosystems across the Auroville forests, and facilitated the long term sustainable management of these forests. Auroville’s prioritisation of principles over prescribed practices has enabled successful and diverse ecosystem restoration, and this approach echoes the call by Higgs (2018) to prioritise the development of guiding principles rather than standards, as these are more culturally and ecologically inclusive.

Table 1

Comparing and Contrasting Practices, Priorities, and Knowledge Systems of Auroville's Seed System and the SER's Seed Standards

	Seed Standards	**Auroville**
Practices	Pre-determined Precise Generalised Rule-based Less accommodating	Community-led Context-dependent Flexible Pragmatic Diverse Individual agency Informed by political reality and community principles
Priorities	Seed quality Transparency of methods and results Enhanced seed supply Orthodox seeds	Conserving rare species Raising high quality seedlings Joy and care in work Sharing knowledge Network building Recalcitrant seeds
Knowledge systems	Empirical One size fits-all Technocratic	Diverse Local Trial and error Intuitive Collaborative Gained through networks Shaped by collective will, fraternity, mutual aid Autonomous

Note. This table provides a brief summary of the analysis sections 1 & 2. Created by author

Discussion & Conclusion

The aim of this research is to evaluate the appropriateness of the Seed Standards (Pedrini et al., 2020), when considering unique restoration contexts. There is scarce literature about this topic even though the Seed Standards were written five years ago with an ambitious task: to be internationally applicable across diverse ecosystems. The results of this study

suggest that, considering the Auroville case study, the Seed Standards fall short in this task: They are not sensitive to socioecological nuances in practice, they prioritise the marketisation of nature, and they ignore diverse forms of knowledge. A few of the Seed Standards guidelines may productively be adapted and applied in local projects in context specific ways, however the results of the Auroville case study indicate that the majority of the guidelines are perceived to be overly technocratic. This study has contributed to filling the literature gap, while adding to a growing body of literature around native seed supply for ecological restoration.

The results of this study suggest that the Seed Standards fail to address the ecological nuances of the Auroville seed system. By imposing arbitrary seed collection ceilings, and applying minimum thresholds of individual species from which to collect seeds, the Seed Standards are not sensitive to the challenges of collecting seed from highly degraded ecosystems. This reflects similar criticism on standards by Higgs et al. (2018). The Seed Standards exclude alternative practices such as using certain seeds of non-native pioneer species for ecological restoration, even though such practices are studied and successful in Auroville and other parts of the world (Ewel & Putz, 2004).

Besides lacking ecological nuance, the Seed Standards also fail to provide a socioecologically sensitive framework. The guidelines presented in the document operate exclusively in a narrow eco-technical paradigm, excluding the highly interrelated social, political, and ecological elements of seed systems. The results of this study indicate that it is important to develop interdisciplinarity in standards. The Auroville case study exemplifies that social and political dimensions are responsible for a seed system's ultimate success and should be addressed. Urzedo et al. (2021) indicate that successful seed supply chains are those that are locally led and stimulated by long-term partnerships between local communities, NGO’s, universities, and government agencies. Maintaining transparency and dialogue

between all stages of the seed supply chain, from collection to planting, is also important to ensure technical feedback loops and a sense of motivation and commitment towards the restoration project (Urzedo et al., 2021). These principles of local leadership and collaborative networks are reflected in the literature and in the Auroville seed system. Future editions of the Seed Standards should include principles in the interest of supporting locally-led, collaborative, and justice oriented seed systems.

The Seed Standards are oriented towards private industries that have high levels of access to resources. As demonstrated in this study, informal seed systems often lack access to resources, making the Seed Standards less applicable. If native seed systems become increasingly regulated and prone to certification (Cross et al., 2020), this unequal access to resources which represents an unequal power distribution will have consequences for the livelihoods of informal seed system practitioners. The power-laden landscape of ecological restoration has been studied, and principles have been developed to address the challenges it presents (Osborne et al., 2021). In this vein, the manifestation of power in the global native seed industry should be uniquely investigated.

The results of this study indicate that the Seed Standards prioritise the development of internationally regulated and tested end products, with high levels of technical and resource intensive procedures geared towards supplier and buyer market settings, prioritising status-quo economies. However, local projects do not always operate within such global market paradigms. As illustrated by the Auroville case study, informal seed systems have local priorities that diverge from the Seed Standards and include developing low resource-intensive practices, studying and applying local ecological knowledge, sharing gained knowledge, and promoting joy in restoration. Seeds are not collected simply to be sold to buyers, but are collected through collaboration and joy, to be propagated and shared throughout the community to increase social and restoration benefits and opportunities. The

different sets of priorities between informal seed systems and standardised seed systems clash with one another. If the Seed Standards aim to be internationally applicable and attractive to informal seed systems, future editions should represent a wider and more inclusive range of priorities.

The importance of informal seed systems in agriculture (Wattnem, 2016) is also relevant in ecological restoration. Informal seed systems are sources of traditional livelihood, community exchange, and they represent sovereignty of seeds. In ecological restoration informal seed systems are quite common because till now the industry has been relatively unregulated at a global scale (Cross et al., 2020). This study has shown how informality is a strength that enables contextualised socioecological practices, such as collecting more than the Seed Standard prescribed amount of seed due to the high levels of degradation around individual specimens, while meeting basic ecological restoration guidelines such as establishing a reference ecosystem. More importantly, informal seed systems are collaborative networks that share the knowledge and joy of working with seeds. Future research should document the characteristics and importance of diverse informal native seed systems to ensure that, at the least, the formalisation of informal seed systems through standardisation and certification schemes remains entirely voluntary for native seed systems, just as it should be for agricultural seed systems as well (Wattnem, 2016).

The results of this study suggest that the standardisation of native seed systems is not necessarily welcomed by local restoration practitioners. These results add to a growing body of literature critiquing the rapid global trend towards native seed standardisation, which leads to the commercialisation of native seed supply by large, often private, market players (Silva et al., 2016; Urzedo et al., 2021). Such trends risk marginalising community-based initiatives and limiting socioeconomic opportunities for indigenous and local communities. In Brazil and Australia, legal and technical frameworks for restoration ecology already act as barriers to the

participation of indigenous and local people (Urzedo et al., 2021). These are environmental justice issues which may become increasingly relevant in the future, seeing how the SER intends to develop certifications and support regulatory approaches that are based on the Seed Standards (Pedrini et al., 2020).

The findings of this study, which highlight how the Seed Standards disregard traditional and local knowledge, resonate with broader critiques of environmental science's epistemological frameworks. Turnhout (2024) argues that dominant environmental science paradigms often marginalise diverse knowledge systems, including Indigenous and local knowledges, thereby hindering transformative change. This oversight in the Seed Standards exemplifies how standardised scientific approaches can exclude the very knowledge systems that are crucial for effective ecological restoration. By not integrating the importance of local and traditional knowledge, the Seed Standards fail to address complex socioecological realities of seed systems. This emphasises the need for more inclusive frameworks that value and incorporate diverse epistemologies to foster equitable and effective environmental governance.

This study has its limitations. I interviewed a small subset of people that are highly involved in Auroville’s seed system, and these may not be representative of the wide range of non-expert and other local stakeholder perspectives. My unique positionality as someone who grew up in Auroville and worked in its seed system has provided me with deep insight and a unique methodological advantage that has shaped the results of this study. This may be difficult to replicate for a researcher who does not have the same relationship with the subject matter. At the same time, this intimate and experiential knowledge of the Auroville seed system might have made it difficult to determine which information to present, and how to do so. Results that seem obvious or irrelevant to me might not be so for the reader. Finally, while my unique positionality affords deep insights into the subject matter, and is considered a

legitimate and productive approach to qualitative research, it also invites criticism of bias and partiality. I have done my best to present the perspectives of the interviewees to their truest form, and I have critically evaluated each of my analyses to maintain accuracy and precision.

In conclusion, this study demonstrates that the Seed Standards, while developed with the intention of international applicability, fall short in addressing the socioecological complexity and knowledge systems of Auroville's seed system. The Seed Standards are geared towards the highly technical and resource intensive marketisation of native seeds, which clashes with the priorities of informal seed systems where collaborative networks share knowledge and joy about working with seeds. The Seed Standards' have a tendency to overlook the restoration challenges of highly degraded ecosystems, making them unattractive to seed system practitioners. These findings contribute to a growing critique of the global push toward standardisation in ecological restoration, particularly when such efforts overlook socioecological nuances and marginalise local knowledge systems. If future editions of the Seed Standards are to be relevant across diverse global contexts, they must embrace interdisciplinarity and include principles that support community-led, collaborative, and diverse knowledge system principles for seed systems.

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